STEEL FRAME RESPONSE TO PUENTE HILLS SCENARIO EARTHQUAKES

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ABSTRACT

- We simulate the response of steel moment frames in several earthquakes on the Puente Hills fault beneath Los Angeles.
- The earthquakes include: M6.7, 6.8, and 7.1 with long-period energy content; and M7.2 with broadband content.
- The building models are fully nonlinear and represent six- and twenty-story buildings with one of two considered strengths and either brittle or ductile welds.
- We compare the results for:
  - several realizations of an earthquake of the fault (*i.e.* scenarios with the same magnitude but different slip distributions and/or hypocenter locations)
  - different magnitudes
  - six- and twenty-story buildings in the broadband ground motions

DESCRIPTION OF SIMULATIONS

- We employ two sets of ground motions:
  - Rob Graves generated ground motions with broadband energy content for a M7.15 earthquake on the Puente Hills fault. The five simulations have different slip distributions and the same hypocenter location.
  - SCEC generate long-period ground motions for M6.7, 6.8, and 7.1 events on one, two, or three segments of the fault. For each magnitude SCEC modeled three slip distributions and two hypocenter locations, giving six realizations.
- We use eight models of example tall, steel, special moment-resisting frame (SMRF) buildings. Each model is characterized by the following:
  - higher strength (design according to the 1992 Japanese Building Code) or lower strength (design according to the 1994 Uniform Building Code), as measured by the base shear at yield
  - six- or twenty-stories
  - brittle or perfect (*i.e.* non-fracturing) welds
  - ❖ Abbreviate model as three letter and number combination. For example, J6P is a model designed to the Japanese Building Code with six-stories and non-fracturing welds.
- We measure building model response with peak inter-story drift ratio (PISDR). FEMA 356 defines damage states to steel frame buildings in terms of PISDR: PISDR < 0.007 allows "immediate occupancy"; PISDR > 0.025 threatens "life safety"; PISDR > 0.05 risks "structural collapse". We deem a model that reaches PISDR > 0.2 a "simulated collapse" since real buildings cannot remain stable at such large drifts.

PUSHOVER CURVES

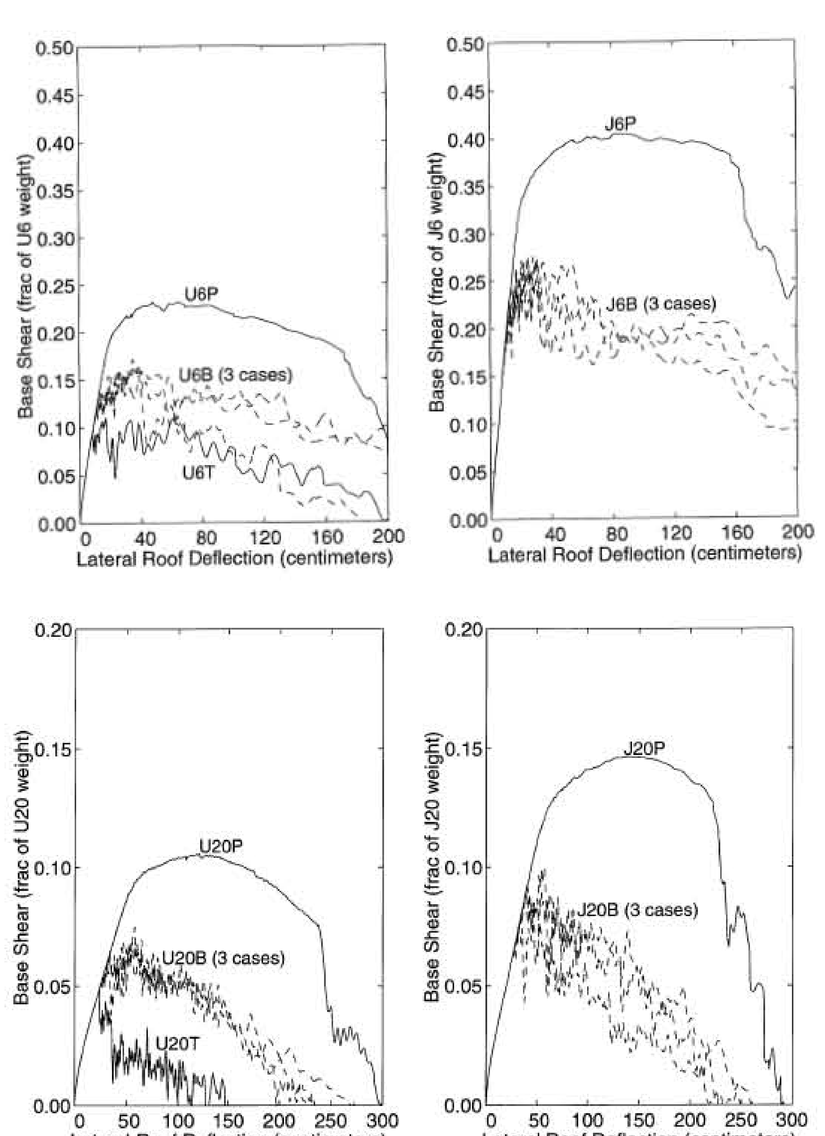
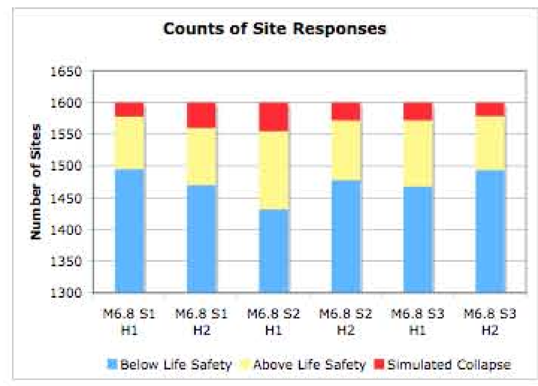
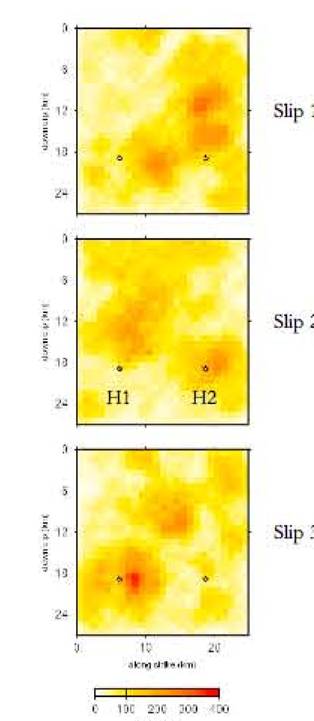
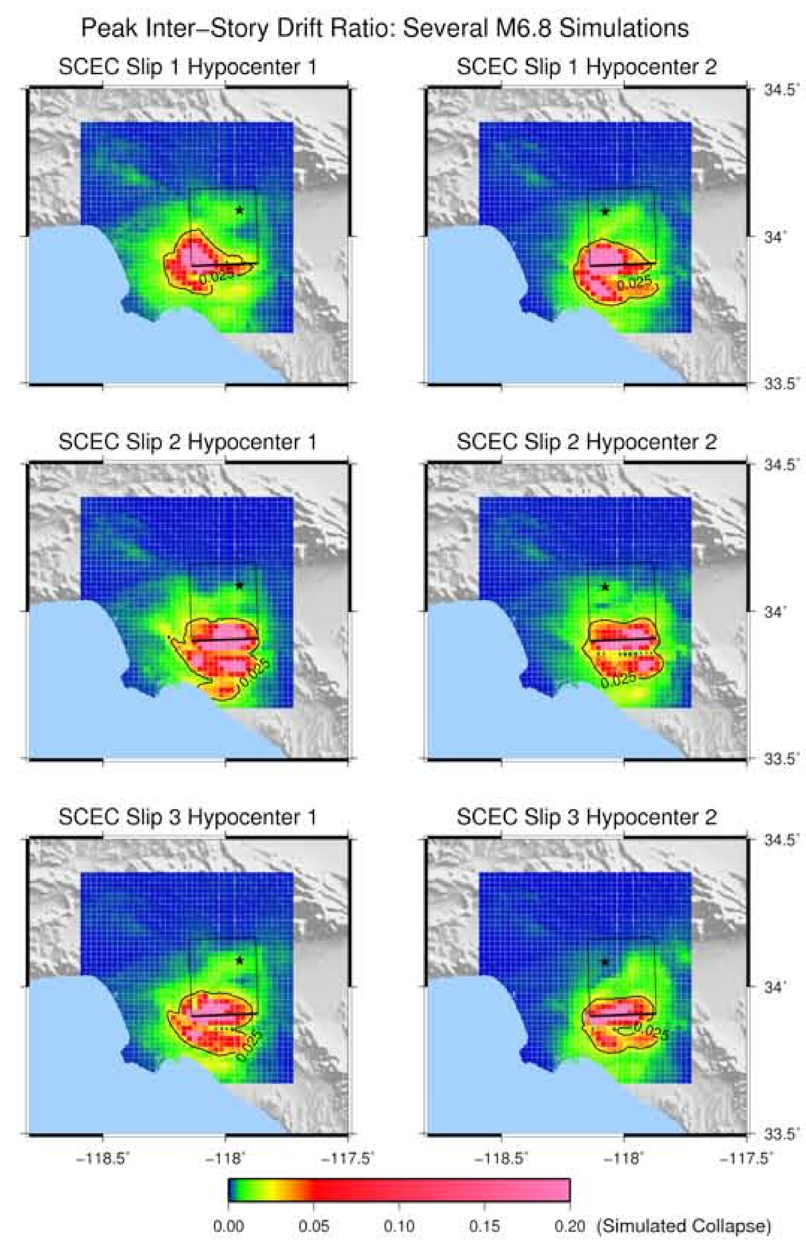


Figure source: Hall, EERL 97-05

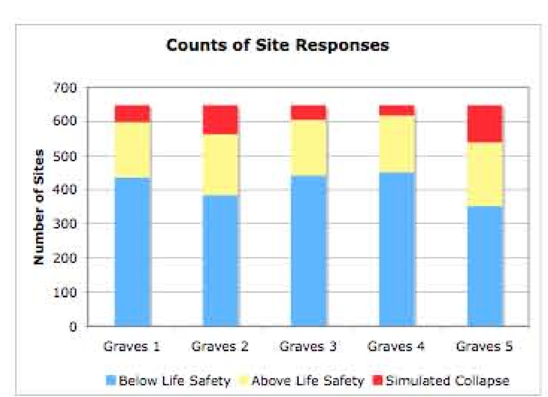
MULTIPLE REALIZATIONS

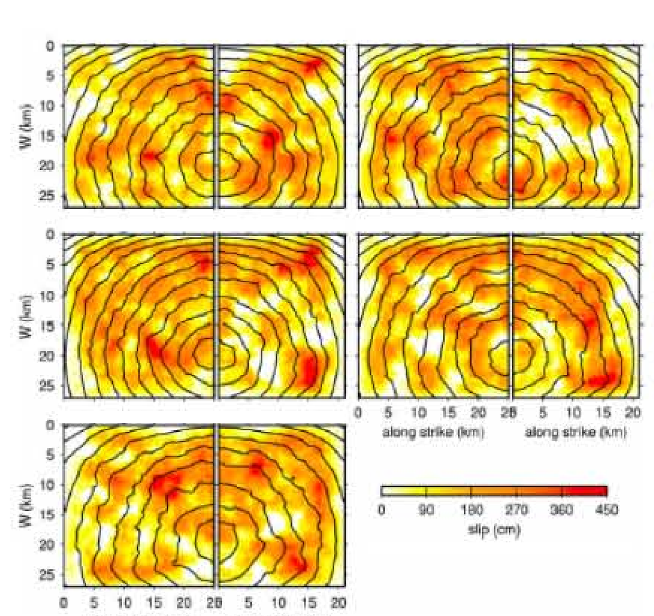


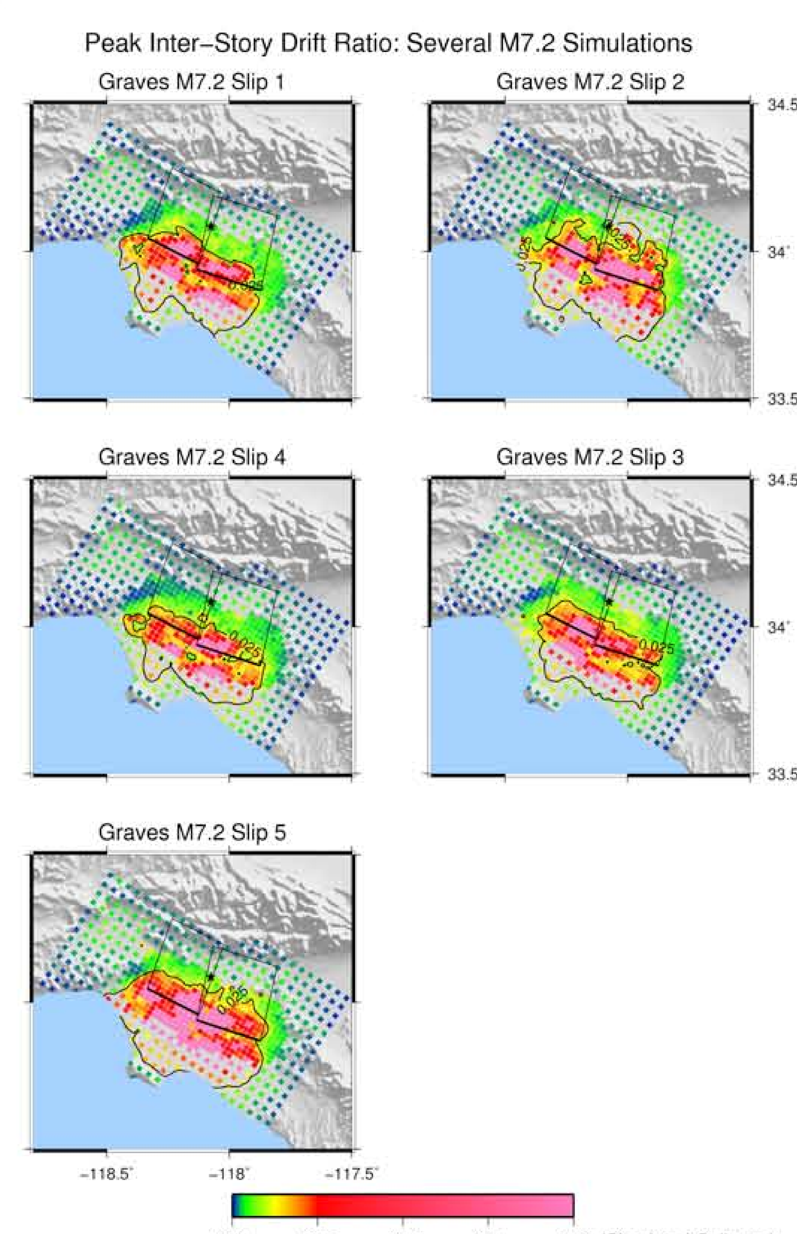




The figures above and below show the U20P model responses to multiple realizations of two scenario earthquakes. The results show variability in the building responses, in terms of both the geographic pattern and the counts of site responses. In general, there are extremely large model responses in the areas up-dip and south of the Puente Hills fault. At specific sites, however, the building responses can vary. These figures demonstrate that conclusions based on a single scenario earthquake must allow for the variability one would see in multiple realizations. One scenario provides a rough estimate of possible building damage, but several scenarios should be run to account for the uncertainty of modeling plausible earthquakes.







ACKNOWLEDGMENTS

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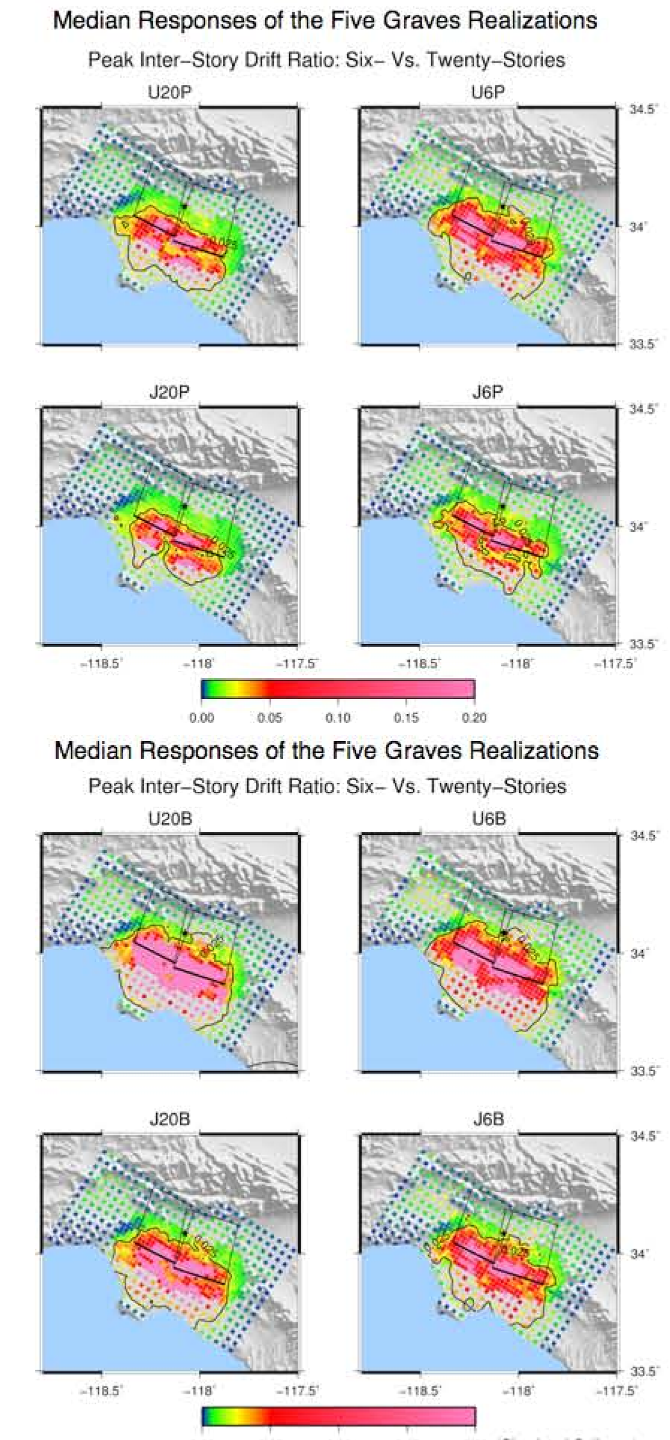
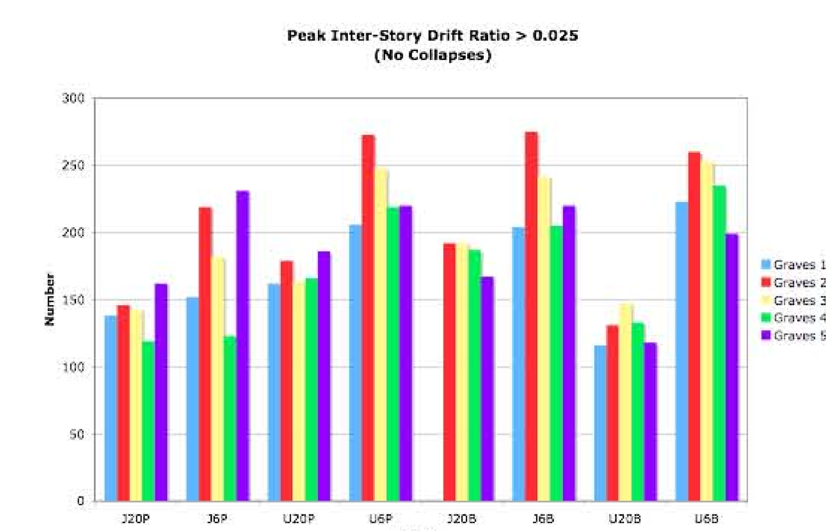
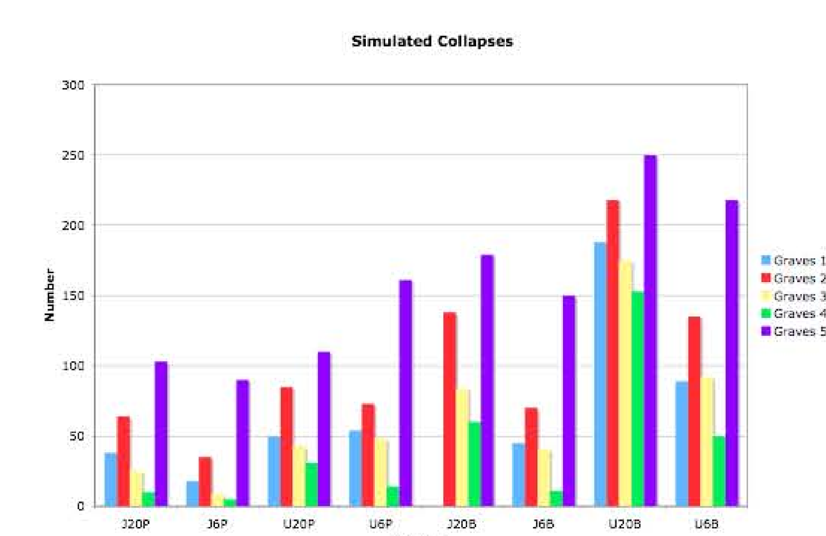
SIX- VS. TWENTY-STORIES





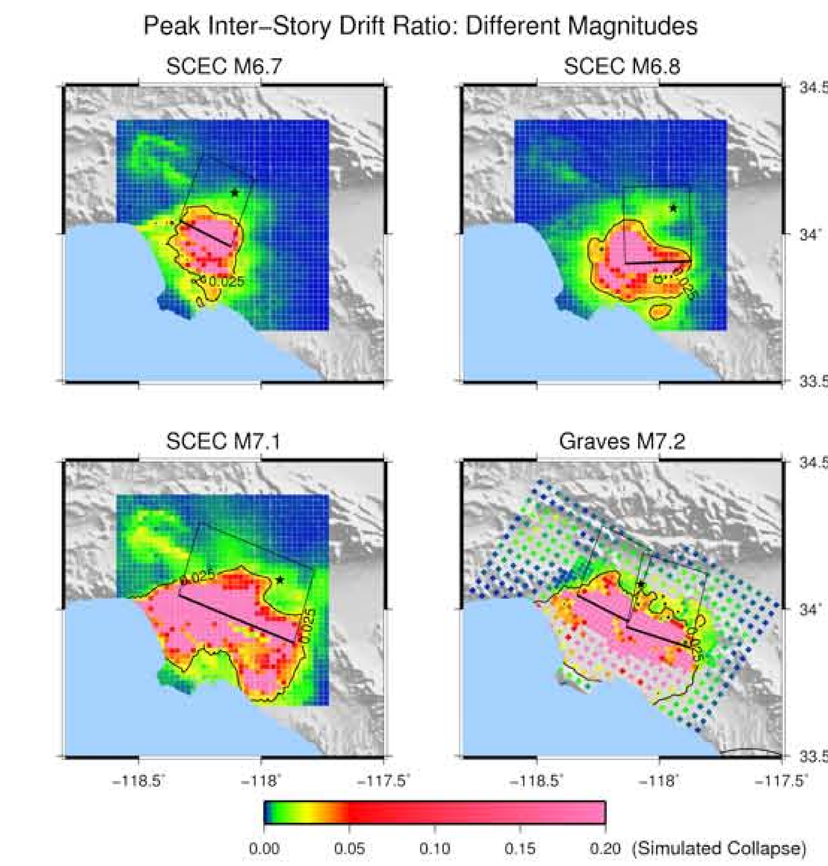


If the models do not show simulated collapse, more six-story buildings exceed life safety (*i.e.* register PISDRs > 0.025) than the equivalent twenty-story buildings.

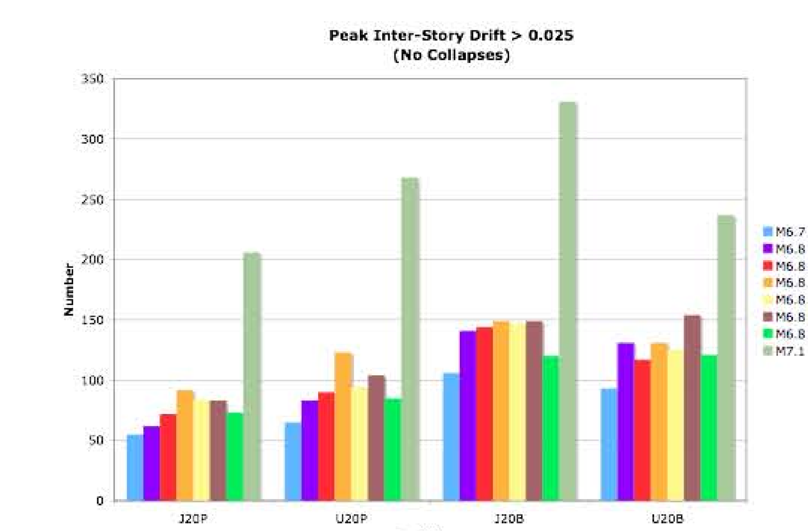
If the models do show simulated collapse, more twenty-story buildings collapse than six-story buildings. The exception to this statement is models with a smaller yield strength and non-fracturing (P) welds: in simulations 1,3, and 5 more six-story models collapse than twenty-story models.

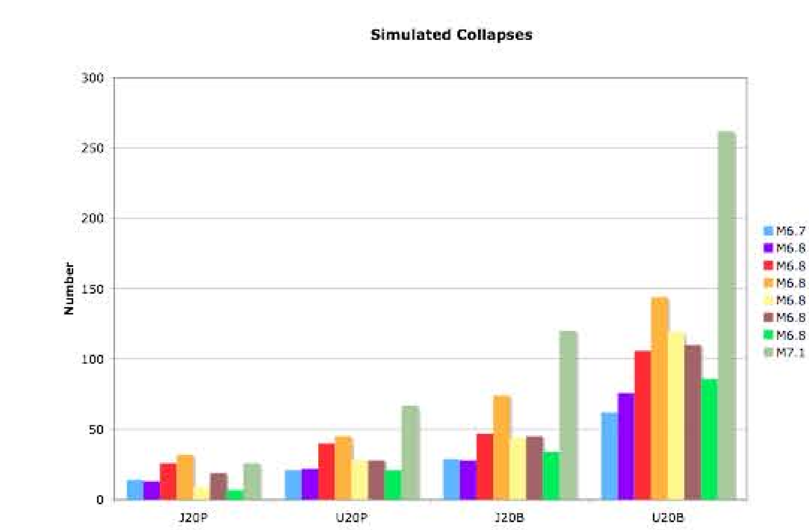
The above two observations are likely explained by the P-Δ effect. Under large lateral deformations, the columns are no longer approximately vertical. This induces an additional moment in the columns, since vertical loads "P" are carried a distance "Δ" from the vertical axis. Since the large drifts are concentrated in the lower stories of models at both heights, the moments due to "P-Δ" are much larger in the twenty-story buildings.

DIFFERENT MAGNITUDES



The above figure shows the response of the U20B model to different magnitude scenarios. As expected, as the magnitude increases more buildings experience large responses to a Puente Hills earthquake. The two largest events cause extremely large building responses on almost the entire Los Angeles basin, compared to a more limited area--but large nonetheless--for the smaller events.





The two above figures show counts of the building responses for the four twenty-story models. Fewer models with non-fracturing welds (P) exceed life safety or show simulated collapse than those with brittle welds (B). Fewer models with a larger yield strength (J) tend to exceed life safety or show simulated collapse than the models with a smaller yield strength (U). The exception is the models with brittle welds that do not collapse: fewer buildings with a smaller strength exceed life safety than do the buildings with a larger strength. However, many more models with a smaller strength and brittle welds collapse than the other three models.

CONCLUSIONS

- At specific sites there can be variability in the building response due to multiple realizations of a scenario earthquake. Conclusions based on a single scenario should consider this variability.
- More twenty-story buildings show simulated collapse than six-stories. If the buildings do not collapse, then more six-story buildings experience peak inter-story drifts that exceed "life safety" (as defined by FEMA 356) than do twenty-story buildings.